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ANALYSIS OF SLAMMING INDUCED WHIPPING EFFECTS OVER THE ULTIMATE STRENGTH OF SHIPS

Résumé

The most common practice to evaluate the ultimate strength of a relatively "soft" floating structure is to compare the maximum dynamic vertical bending moment (VBM) after a slamming event, which is derived from hydro-elastic calculations, with the quasi-static hull girder capacity. In other words, the structural behavior is considered as linear and elastic in the hydro-elastic coupling, and as non-linear elastoplastic in the ultimate strength evaluation. Therefore, some doubts are cast on the capability of the current hydro-elastic methods to accurately predict the extreme dynamic response on the basis of a linear elastic structural model. Aside from that, the whipping induced stresses have a higher frequency than the ordinary wave-induced stresses; hence, the dynamic effects such as inertia and strain rate effects may provide additional strength reserves for the ship structure and should be investigated.

The first part of the thesis is dedicated to the numerical investigations of dynamic ultimate strength for various ship structures. In order to analyze the influence of the inertia and strain rate effects, different load functions are used, starting from the simplest ones where the loads are defined as half-sine functions, to more realistic ones where the loads are represented by equivalent design waves. The dynamic ultimate strength is defined as the maximum load level that leads to a non-collapse scenario, and it is determined through a newly developed iterative algorithm. Finally, the dynamic ultimate strength is compared with the quasi-static ultimate strength, and the dynamic load factors are derived in order to obtain a proper estimator of the dynamic collapse effect.

The second part of the thesis is dedicated to the development of a new method to calculate the non-linear whipping response, where the elastoplastic structural response is considered. Although modern container ships are of truly gigantic size, for the purpose of dynamic analysis, such ships can be very well represented as a thin beam. Furthermore, it is essential to take into account that in real cases, only a very limited extent of the structure collapses. Therefore, the hull girder is modeled as two non-uniform Timoshenko beams, connected with a non-linear hinge, described by the non-linear relation between the internal bending moment and the relative rotation angle. The exact coupling between the structural model and the 3D hydrodynamic model is achieved by constructing the hydrodynamic boundary value problem for each shape function of the finite element, and the fully coupled hydro-elastoplastic problem is solved within a partly non-linear time-domain seakeeping program. The proposed model allows for reasonably fast computations of non-linear whipping response, and therefore it can be applied to calculate the response of the hull girder for a series of equivalent design waves, or design sea states. Finally, the non-linear whipping response is compared with the linear whipping response in order to derive the whipping reduction coefficients.

Mots-clés: dynamic ultimate strength, non-linear whipping, hydro-elastoplasticity, fluid structure interaction

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